High-Performance Parallel Processing Project—Industrial Computing Initiative

Effective Collaboration to Increase Productivity and Competitiveness

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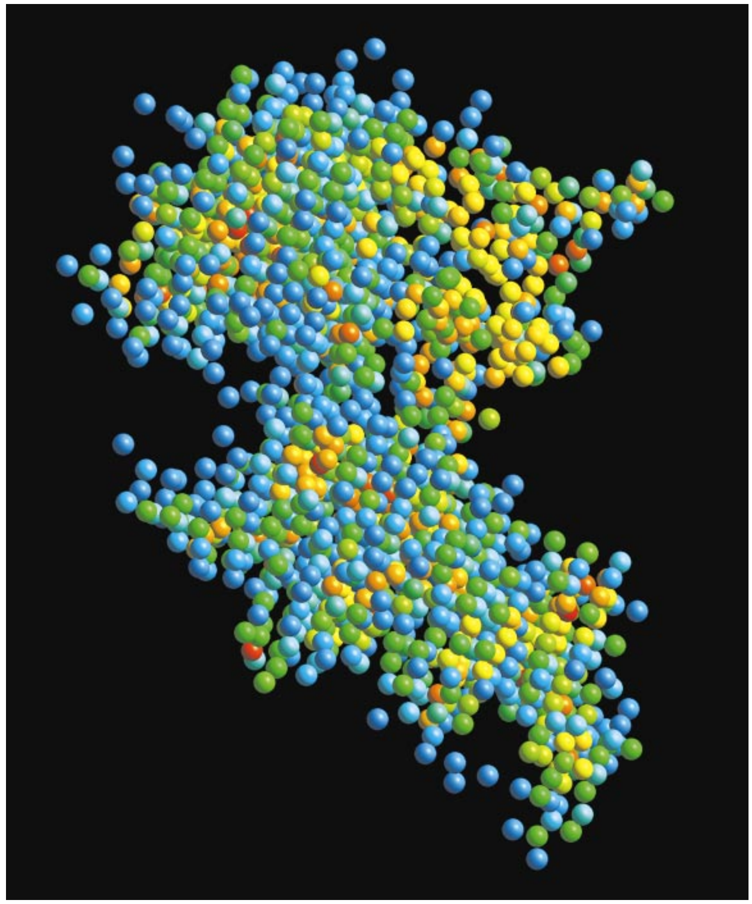

A region of amorphous silicon left behind after thermalization of a displacement cascade initiated by a 5-keV silicon implantation event. The amorphous material in this region is in a highly non-equilibrium state and contains large density fluctuations (defects).

Objectives

In this three-year, multiparty collaboration begun in 1994, we are addressing several problems that have limited more widespread use of massively parallel computing by researchers in government, academia, and industry. Our goal is to deliver a set of tools and efficient parallel application codes, which will accelerate the use of high-performance parallel processing and thus increase U.S. industrial productivity and competitiveness.

Applications

Computer simulation and modeling are helping industry become more competitive by reducing design cost, decreasing time to market, and improving the final product. This technology can be applied to a wide range of industrial products and processes, including modeling the climate or the movement of groundwater, designing semiconductors, modeling manufacturing processes, and developing new products.

The Industrial Computing Initiative (ICI) is a cooperative research project involving Lawrence Livermore and Los Alamos national laboratories (LLNL and LANL), Cray Research, Inc., and 12 other industrial partners. The ICI represents the largest component of the High-Performance Parallel Processing Project (H4P). By improving simulations and modeling of physical systems, we can provide accurate input at the design stage of both product and process. As a result, we can help U.S. industry produce better products faster and with less expense.

The H4P-ICI research allows both LLNL and LANL to use computational expertise developed as part of defense or energy research to solve new industrial problems. Application areas include semiconductor material and device design, environmental remediation and prediction, molding and manufacturing, petroleum exploration, communication, and structural design and evaluation.

A New Technology for New Problems

For this research, Cray Research sited two T3D massively parallel processors (MPPs), one at LLNL and the other at LANL, in 1994. The CRAY T3D at LLNL is a massively parallel supercomputer with 256 processing elements and is based on the DEC EV-4 (Alpha) chip. These chips, each with its own memory, are connected by a very fast communications network into a toroidal mesh of processors. The processors simultaneously work on a given computation or can be divided up to work on several different computations.

Although traditional supercomputers have been used for modeling for many years, eventually they are limited in memory or computing power. The MPP distributes the memory among the processors, so that many large memories can be managed, each by its own processor. Likewise, while the speed limit of an individual supercomputing processor has not yet been reached, in some problems it is cost-effective to use many smaller, less expensive processors, each assigned to a small part of the larger task. The difficulty has been in developing new software, hardware, and algorithms to make such machines both efficient and usable.

To make effective use of the MPPs, we provide them with schedulers, languages, and tools that allow algorithms to be run simply and efficiently. In one project, we have developed a gang scheduler, (see http://coral.llnl.gov/dctg/gang/sc96.summary.html), which allows jobs to be swapped in and out of an MPP. This scheduler thus provides for efficient use of the computing resource. Cray Research and LLNL are working together to make this scheduling tool available to other T3D sites. We are also working on versions for other MPP platforms.

Simulation and Modeling: Tools for Competitiveness

The following examples of products we are developing reflect the diversity of American industry and the flexibility of this approach.

- Groundwater contamination is difficult to remediate because pollutants seeping into the soil can vary dramatically at a given site. We model this effect on the MPPs and use the results to determine optimal points and rates of pumping for groundwater protection.
- We model molecules in a material or surface to determine the usefulness of a given material and the effects of impurities introduced into it. New materials can then be matched directly to the application requiring them.
- In one oil-exploration technique, nuclear material is lowered into a test borehole where the intensity and energies of emitted neutrons are measured by sensors surrounding it. From these measurements, a picture of the materials surrounding the test borehole can be made and evaluated to determine the location of petroleum and the difficulty of extracting it. One such application uses almost two-thirds of the peak speed of the T3D in running neutron-transport simulations, providing an unprecedented modeling capability that could revolutionize the way we search for and extract raw materials from the earth.

Effective Collaboration

This project makes it truly cost-effective for industrial participants to evaluate, develop, and apply massively parallel computational tools because the cost and risk of developing industrial applications is divided among the 15 members of the consortium. Furthermore, the national laboratories use their computational technology and expertise to take advantage of the capabilities of the machine. In this way, the laboratories maintain their mission and importance to national security; industry obtains tools to improve profitability and expand the national economy; and the computer manufacturer develops new markets based on the needs of the industrial participants. In short, the consortium approach focuses the efforts of each of the participants on what they do best for the benefit of all.

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